ESTIMATION OF LAYER THICKNESS OF ARTERIO-CAROTIS USING DYNAMIC PROGRAMMING PROCEDURE

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Abstract - **The Intima Media Thickness (IMT) of different subjects is estimated by using Dynamic Programming (DP) procedure and presented in this paper. A Non invasive B-Mode Ultrasonic imaging of Common Carotid Artery (CCA) is used for estimating the optimal solution for an image features and geometrical characteristics of vessel interfaces. The proposed procedure facilitates the measurement of near wall features. IMT is estimated as 0.898mm and 1.933mm for the normal subject and the abnormal subject (atherosclerosis) respectively. The proposed DP procedure considering the near wall features can be used as a reliable system to predict the fatal complications such as heart attack and stroke.**

Index Terms: atherosclerosis, B-Mode Ultrasonic image, Common Carotid artery (CCA), Dynamic Programming (DP),Intima Media Thickness(IMT).

I. INTRODUCTION

In recent years, it has been shown that the B mode ultrasound images can be used for non-invasive and quantative measures to diagnose the cardiovascular pathologies [1]. Non-invasive B mode imaging is used for studying progress and regress of atherosclerotic lesions in the carotid artery [2]. The presence of the disease can be subjected to changes in layers that affect the normal flow of blood in the artery. This change in the layer (such as stenosis or plaques) represents a risk index for several pathologies like acute stroke or cardiac infarction. It is well known that an increased thickness of the CCA wall is correlated with a higher incidence of cardiovascular and cerebral acute events.

The CCA wall consists of three different layers: an internal tunica (intima), a thick layer of transversal muscular tissues (media), and an external and more connective layer (adventitia). In particular, the intima-media thickness (IMT) is correlated with an augmented risk of severe pathologies. Hence, the analysis of the CCA layers is of paramount importance for an effective evaluation of a patient.

Clinically acquired B-mode images frequently have weak echoes, echo dropouts, and speckle noise making them difficult to analyze using conventional boundary detection technique [2]. The IMT measurement with B-Mode sonography technique is simple and generally considered as reproducible, but one important limitation lies in its ability to distinguish the intimal from medial layers [3]. IMT is defined as the distance between the leading edge of the first echogenic line (lumen-intima interface) and the second echogenic line (media-adventitia interface) of the arterial wall [4].

The IMT thickness of CCA can be used to predict atherosclerotic lesions as well as myocardial infarctions and stroke in several epidemiological and clinical studies. In order to determine the interface location, computer-based interactive tracing systems are commonly used [5]. The manual tracing approach, however, is time consuming and is based on subjective operator assessment. Furthermore, manual tracing may cause a drift in measurements over time [6].

More number of research articles has been published by researchers world wide to find the techniques for boundary estimation in ultrasonic arterial images. P. J. Touboul, *et al.* [9] have performed the measurement on regular arterial segments where the intensity profile showed clear two-pulse patterns which corresponded to echoes from the lumen–intima and media–adventitia interfaces. In their work the locations are assigned by operator whereas IMT was automatically determined by the computer. Later, J. Gariepy *et al.* [10] expressed that the operator traced the position of the wall and then the computer located the lumen–intima and media–adventitia interfaces by discriminating changes in gray levels, whereas Selzer *et al.* described a multistep procedure [11]. First, the approximate position of the boundary was manually traced. The IMT was finally computed as the mean distance between accepted pixel pairs. Quan Liang, Inger Wendelhag *et al* stated that the Dynamic programming procedure was used to detect the Layers from the far wall of CCA.

This paper presents dynamic programming Procedure [3] to measure the echo intensity, the intensity gradient of the image, and the boundary geometrical constraints. It includes the echo dropouts for to estimate the continuity in the points of the polyline in the near wall. These are included as weighted terms in the global evaluation function, the cost function. The DP method is normally operator independent and requires few human modifications. Therefore entire process is significantly simplified. Variability due to human factors is thus reduced. The processing time is considerably

reduced. Keeping the facts in view the present paper aims to develop a linear programming scheme to estimate the intima-media thickness of the near wall to make decision on the characteristics of the wall.

II. METHODS

A. *Image Acquisition:*

The arterial movements are recorded by the US machine (Prosound Alpha-10 from Aloka).With the Compound Pulse Wave, Generator Aloka is able to control the waveform on a performance level. The result is an exceptional precise beam, providing enhancements in focus accuracy, spatial and contrast resolution. The probe used is a multifrequency probe of range 5–10 MHz. For this application, the frequency is set at 7.5 MHz. The probe is placed exactly at the bifurcation of the common carotid artery for uniformity in measurement in all the subjects. A 10-s movie is recorded for each subject showing the movement of common carotid artery in B-mode. Movement of carotid artery is recorded in a way; it shows the longitudinal section for the subject. The movie is then processed and stored as a sequence of still images. The noise created during US scanning leads to difficulty in defining the boundary of the vessel.

B. *Preprocessing procedures:*

Carotid images have been preprocessed for applying DP procedure. An average intensity histogram is computed by intensity normalization procedure [4]. The images are smoothed horizontally to overcome the difficulties of echo dropouts [8].

C. *Characteristics of Ultrasonic carotid artery Image:*

Figure 1 (a) shows a representative image of the carotid artery and Figure 1 (b) shows a schematic illustration of echo zones (Z1-Z7) and relevant vessel interfaces (I2,I3,I5,I7) of the near wall and far wall . IMT is defined as the distance between I2 and I3 for the near wall and I5 and I7 for the far wall [7] .Lumen Diameter (LD) is the distance between I3 and I5.

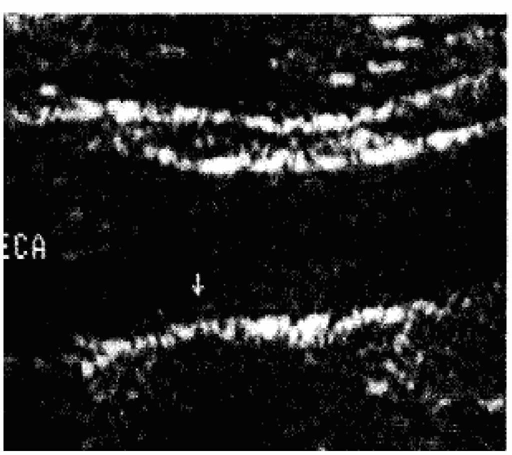

Fig. 1. (a) Carotid artery image.

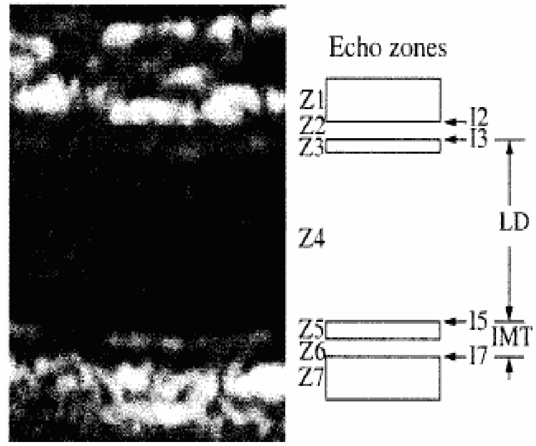

Fig.1 (b). Definition of echo zones and interfaces.

D. *Location of interfaces:*

Initially the vessel interfaces in a vertical wall position is determined by the operation of strong smoothing filter to the image. The start position in the horizontal wall is stated by the perceiver [5]. The process is done to achieve the blurring of vessel interfaces [8]. Finally the near wall is detected by applying the Dynamic programming procedure.

E. *The Cost Functions and Cost Terms*

Cost functions are built for each of the interested boundaries I2 and I3 of CCA near wall is shown in Fig.1.(b).ROI is selected from original image as in Fig.2.A Deformal polyline $\mathbf{B_N}$ is considered from M X N of ROI. The polyline containing N nodes, one in each column composed of M candidates, i.e., $B_N=\{p_1, p_2, p_3$ and $p_N\}$ .The cost function denoted as $C(B_N)$ is defined[7] as a sum of local costs along a candidate boundary or the polyline B_N.

$$C\{p_1, p_2, p_3, p_N, N\} = cF(p_1) + \sum_{i=2}^{N} (c_F(p_i) + c_G)(p_{i-1}, p_i) \tag{1}$$

where the local cost at $\mathbf{p_i}$ is composed of two terms

$$c_F(p_i) = \sum_{j=1}^{k} W_j f_j(p_i)(i = 1,2,......., N) \tag{2}$$

$$c_G(p_{1-1}, p_i) = W_{k+1} g(p_{i-1,} p_i)(1,2,3,....N) \tag{3}$$

in which $\mathbf{f_j(p_i)(j=1,\dots, K)}$. are image feature terms.

It is specifically designed so that a stronger image feature at (p_i) will yields a lower $f_j(p_i)$ output. The lower the $f_j(p_i)$**,**output values will exerts a stronger attracting force on the polyline. The term $g(p_{i-1,}p_i)$ represents the geometrical force. A smaller difference between the vertical positions of p_i and p_{i-1} yields a lower value and hence, a lower local cost which means the connection between p_i and p_{i-1} is more favored. The desired boundary $\hat{B}_N$ is optimal $\mathbf{B_N}$ which minimizes $C(B_N)$.

$$\hat{B}_N = \{B_N \mid \min(C(B_N))\} \quad (4)$$

The optimal solution of the cost function is the desired boundary.

F. *Dynamic Programming:*

The dynamic programming algorithm is an optimization of the cost function by finding optimal polyline, corresponding to the artery boundary[6].In DP ,the Cost function is a weighted sum of echo intensity, intensity gradient and boundary continuity cost terms[7] at each pixel. The optimality [8] is achieved by minimizing the cost functions .It is shown in Fig.4 and 5

$$\mathbf{C(p_{1},1) = c_F(p_1) \quad C\{p_1,p_2 \ ,p_3 \ \text{and} \quad p_n \ ,n\} = c_F(p_1) + \{\Sigma c_F(p_i)+c_G(p_{i-1},p_i)\}+\{c_F(p_n)+c_G(p_{n-1},p_n)\}} \quad (5)$$

The summation in (1) is expressed as an N-1 -stage process, so that the DP procedure can be applied to derive the desired boundary by minimizing the cost function. The computational complexity is reduced in this boundary detection.

G. *Implementation*

Step1: Image acquisition using ultrasound system.
Step2: Identification of the near wall (ROI).
Step3: Histogram evaluation to detect the intensity of the image.
Step4: Horizontal smooth filtering to remove echo dropouts in US images.
Step5: Blurring is done to locate the vessel interfaces.
Step6: Determination of the Cost function for each point in the polylines of ROI.
Step7: Estimation of the boundaries by optimizing the cost function.
Step8: Measuring the distance between the intimal and medial layers of the near wall of ROI image.
Step9: Comparing the IMT of various subjects with normal subjects.

III.RESULTS

The images of CCA have been obtained using ultrasound scanner (Prosound α-10) and the procedure is mentioned in the previous section has been applied. Fig.2 is a sample frame extracted from the recorded test video showing the transversal section of the Common Carotid artery in B-mode. In the sample image ROI portion is highlighted and is shown in Fig.3. The maximum intensity pixels of the adventitial layers are marked by cross(x) marks and the lumen intensity pixels with minimum value are marked by dots. This marking helps to locate the starting and ending point of intima –lumen interfaces and adventitia – media interfaces in a polyline. The cumulative cost values obtained by the DP procedure are shown in Fig. 4. and the cost curve at the every column of the ROI image is shown in Fig 5. This cost curve indicates the minimum cost function in the polyline, which is pointed out by means of arrow in Fig.5. The View of the near wall layer for the normal subject is shown in Fig.6.The Intima Media Thickness has been estimated by considering the pixel counts. It has been shown by many researchers that 1mm is approximately equal to 8.52 pixels. As a result of determination, it has been found this IMT for the normal object is 0.858mm.Fig.7.shows the view of near wall layer for the abnormal subject. It has been measured that the IMT is 1.933mm.The boundary coordinates and measurements of IMT are stored on disk for subsequent use as expert data.

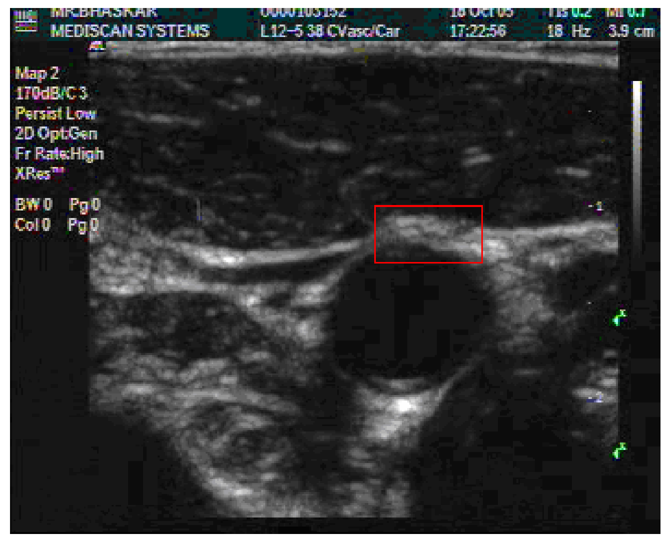

Fig.2 Original image

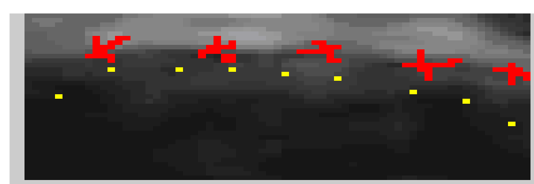

Fig.3 Image used for dynamic Programming

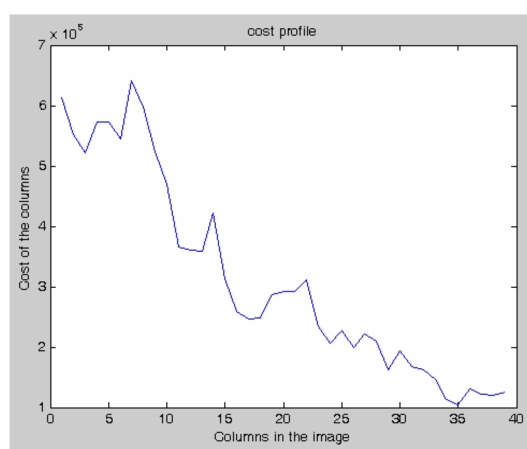

Fig.4 Cumulative Cost curve for the entire image

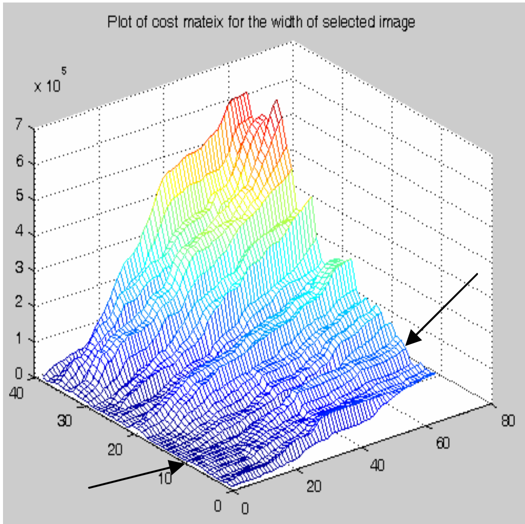

Fig.5 Cost curve at every column of the image.

Fig .6.View of near wall layers for Normal subject.

Fig .7.View of near wall layers for abnormal subject.

IV.Conclusion

This paper proposes a method of detecting the atherosclerosis using B-Mode ultrasound image by dynamic programming procedure. It has been found that the IMT for normal and abnormal cases are below and above 1mm respectively. It overcomes the difficulties of conventional detection procedure.. It is concluded that DP algorithm for IMT is preferable for monitoring patient's atherosclerosis state.

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